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NO-TILL DRILL DESIGN FOR ATRAZINE TREATED SOILS

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SUMMARY:

A no-till drill was designed to provide placement selectivity for wheat planted on atrazine treated soils. Modified hoe openers move atrazine treated soil and weed seed from the row leaving a herbicide free zone in which wheat could grow. Atrazine was applied at high rates to control cheat without significantly reducing wheat stands and yields.

No-Till Drill Design for Atrazine Treated Soils

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INTRODUCTION

Weed and volunteer crop growth must be controlled for conservation tillage practices to be successfully used for winter wheat (Triticum aestivum L.) production. Herbicides have been successfully used to control weeds during the three to four month fallow period between wheat crops in Oklahoma. However, winter annual weeds, particularly downy brome (Bromus tectorum L.) and cheat (Bromus secalinus L.) are difficult to control. Metribuzin (4-amino-6-(1,1--dimethylethyl)-3-(methylthio)-1,2,4-triazine-5(4H)-one) is labeled for control of these weeds in Oklahoma. However, the herbicide is relatively expensive and weed control can be erratic. Metribuzin can cause significant injury to wheat.

Other triazine herbicides such as atrazine (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) can effectively control cheat and downy brome and cost less than metribuzin. However, atrazine can be toxic to wheat at application rates which produce satisfactory weed control. Although atrazine lacks physiological selectivity, the potential cost advantage resulting if it could be used stimulates the need to determine whether this herbicide could be used with some form of placement selectivity. One way of obtaining placement selectivity may be applying atrazine immediately prior to sowing wheat. The atrazine treated soil could be removed from the vicinity of the row creating an atrazine free zone around the seed. Weeds could germinate and emerge in this zone without translocating significant amounts of the herbicide. Weed seeds would be removed from this zone and placed between the rows where atrazine would be concentrated. This approach has the potential for near or complete control of winter annual grasses in wheat, with minimal injury to the crop.

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To determine if placement could be used to improve atrazine selectivity in wheat, research was conducted with the following objectives:

(1) Design and construct a grain drill capable of removing atrazine treated soil from the drill row.

(2) Evaluate effects of removing atrazine treated soil from the drill row on stands, forage production, and grain yield of wheat.

This paper reports results of the research.

REVIEW OF LITERATURE

Wittmuss et al. (1971) discussed a till-plant system which implemented the concept of removing crop residue and weed seed from the row to improve stand and to reduce competition from weeds within the row. They used a strip till-planter consisting of a rolling coulter to cut through crop residue followed by a sweep to remove residue and weed seed from the row. The crop was planted on ridges formed during cultivation the previous year. The till-plant system produced corn and grain sorghum yields equal to conventional tillage systems. The till-planter eliminated volunteer corn in the row by killing the growing plants with the sweep and by moving the seed from the row into the area between the rows where it was killed during cultivation.

An extensive body of literature exists on no-till planter and drill design to minimize draft and vertical forces. Smooth coulters approximately 46 cm in diameter have been found to do the best job of cutting through heavy straw residues (Krall et al., 1978; Schaaf et al., 1980; and Vaishnav et al., 1982). Schaaf et al. (1981) compared draft and vertical forces of spear point, spike, hoe, semi-deep furrow, and double disc openers. The double disc opener had the highest vertical force requirement, the spike opener the lowest vertical force requirement, and the semi-deep furrow opener the highest draft requirement. Krall et al. (1978) reported very narrow openers, such as the double disc openers, and spike handled straw better and created better seedbeds than spear points and 10 cm shovels. No differences were observed in performances of all types of press wheels in small grains. Schaaf et al. (1981) recommended that press wheel width be equal to or less than the width of the soil influenced by the opener.

The effect of geometry on vertical force and draft of concave discs used to move soil has been studied extensively. Reaves et al. (1981) reported that discs with the ratio of disc diameter to radius of curvature of 1 to 2 had lowest draft, vertical force, and side draft. Gill et al. (1980) noted that the optimum angle to operate a disc was about 25° to 32°. None of these researchers studied the effects of selection or design on the component's ability to remove herbicide treated soils from the drill row.

Since minimizing atrazine contact with the wheat plant is essential, both the application rate and movement of the herbicide in the soil directly affect drill design and operation. Fenster et al. (1965) obtained 100% control of downy brome with atrazine applied at rates of 2.2 kg/ha. In a silt loam, atrazine rates of 2.2 kg/ha did not cause injury to wheat planted 6 to 12 months later. In a fine sandy loam, wheat injury occurred at rates of 1.8 kg/ha. When atrazine was applied at 3.6 kg/ha, severe wheat injury occurred in both soil types.

Burnside et al. (1963) showed that atrazine in small amounts leached 30 to 45 cm into the soil. Occasionally, rates of 2 kg/ha injured wheat plants, but tillering increased to make up for losses. With furrow irrigation, atrazine moved laterally through the soil about 7.5 cm (Ashton, 1961). Birk and Roadhouse (1964) found that very little atrazine, applied at rates from 2 to 20 kg/ha, moved from the top 1.7 cm of soil. Slack et al. (1978) reported that s-triazines dissipated faster in no-till than conventionally tilled corn.

DRILL DESIGN

If atrazine is to be used at high rates to control cheat in no-till wheat, a drill must be designed to remove surface applied atrazine and about 3.5 cm of treated soil from the drill row. Width of the treated soil band to be removed at planting may need to be as wide as 15 cm. At least two methods could be used to remove herbicide treated soil ahead of the drill openers. A modified hoe opener or sweep should be capable of pushing treated soil to either side of the row. A concave disc mounted ahead of the opener could move relatively large amounts of soil, depositing the material between the rows.

An experimental drill was constructed to evaluate selected components for use in removing atrazine treated soil from drill rows by either of the porposed methods. The drill consisted of a square tubular steel frame mounted on a tractor three point hitch. A modified Wil-Rich air seeder metering unit was attached to the frame (Fig. 1). The rubber roll metering unit, blower, and gasoline engine to drive the blower were retained. Seed and fertilizer hoppers were replaced with hoppers of 1/4 the original capacity. The air manifold was rebuilt to fit between the metering unit and frame. Seed dropped from the metering rolls into individual seed cups for each row. Seed was then entrained into the air stream, exiting the cups through hoses inserted into the furrow openers.

Eight opener units were constructed by welding 10 by 10 cm box beams to parallel 4-bar linkages. Each unit was bolted to the planter frame. Combinations of coulters, openers, and press wheels were bolted to the box beams for testing.

Air cylinders provided down pressure for each unit. A tractor engine driven air compressor supplied air to the cylinders.

Components selected for evaluation included: Fleischer Manufacturing Company disc hillers with 46 and 56 cm diameter disc blades; John Deere LZ drill shanks and spear point hoe openers; Tye double disc openers; 2.5 cm by 25 cm cast iron center press wheels; and John Deere 10 cm by 30 cm rubber tire Vee press wheels. Fleischer

Manufacturing Company coulter gauge wheels were bolted to the box beams of all units immediately behind the 4-bar parallel linkages. Disc hillers could be mounted immediately behind the coulter gauge wheels to remove treated soil and deposit it between drill rows (Fig. 2). Width and depth of treated soil removed could be varied by changing disc angle and operating depth.

Double disc or hoe openers were bolted to brackets which were clamped to the box beams. Openers could be spaced on 25 cm intervals or on paired row spacings (Fig. 3). Paired row spacings consisted of alternating 13 and 38 cm row spacings. The 38 cm spacing provided additional area for depositing soil removed by the disc hiller. The 46 cm diameter concave disc was used with uniformly spaced openers; the 56 cm in diameter disc was used when openers were paired. A 2.5 by 25 cm press wheels was attached behind each openers.

Design of Modified Openers

The spear point opener was used as a basis for developing a modified opener that combined the soil moving characteristics of the concave disc with a hoe furrow opener. The spear point cleared a 2.5 cm wide path through treated soil. Modified hoes were designed to clear paths of treated soil 5 cm and 10 cm wide.

The 5 cm path was cleared by mounting wings on each side of the hoe opener. Wings were positioned so that treated soil was seperated from clean soil as soil flowed around the opener (Fig. 4). This soil saperation occurred above ground level, reducing vertical force requirements by not forcing the wings into the soil. A 10 cm wide path was cleared by mounting larger wings on the hoe opener. To provide the additional soil movement, the wings were extended further down on the opener. A 10 by 30 cm rubber tire Vee press wheel on the 2.5 by 25 cm press wheel could be attached to firm the furrow walls to prevent treated soil from falling back into the furrow (Fig. 5).

METHODS AND PROCEDURE

Experiments were conducted to determine the seedling environment created by each set of components selected, and to determine if concave discs or winged hoe openers could be used to remove herbicide treated soil from the drill row while maintaining weed control. Components were tested in no tillage and minimum tillage systems with no herbicide and in atrazine treated soils. The previous crop in all experiments was wheat.

Component Effects on Seed Environment

Six different component combinations were evaluated for effect on seedling environment in no tillage and minimum tillage conditions. Plots were planted on two dates at each location. Planter component combinations tested included:

1. Gauge coulter and spear point hoe opener with units on 25 cm row spacings (hoe treatment).

2. Gauge coulter and double disc opener with units on 25 cm row spacings (double disc treatment).

3. Gauge coulter followed by 46 cm concave disc and spear point hoe opener, units on 25 cm row spacings (concave disc hoe treatment).

4. Gauge coulter followed by paired spear point hoe openers (paired hoe treatment).

5. Gauge coulter followed by 56 cm concave disc, followed by paired spear point hoe openers (concave disc paired hoe treatment).

6. Gauge coulter followed by 56 cm concave disc and paired double disc openers (concave disc paired double disc treatment).

No tillage experiments were located at Agronomy Research Station, Perkins, OK, on a Zaneis loam (thermic Udic Haplustolls). Plots were planted on October 2 and 19, 1984 with Tam W101 wheat (Triticum aestivum L.) and cut for grain yields on May 30, 1985.

Minimum tillage experiments were located at Lake Carl Blackwell Experimental Range Area, Stillwater, OK, on a Port loam (thermic Cumulic Haplustolls). At this location, TAM W101 wheat was planted on October 11 and November 6, 1984. All plots were undercut with Miller-W 3.3 m wide 2 section V-blade. Weeds were controlled with a Miller-W rodweeder with semi-chisels during the summer. Immediately prior to the second date of planting plots were tilled with a Richardson mulch treader to control late germinating weeds. The first planting date was combined on June 10 and the second planting date on June 25, 1985.

A randomized complete block design with four replications was used at each location and date of planting. Stand counts were taken after the seedlings emerged. Seedling stress was evaluated with the method described by Klepper et al. (1982). Klepper reported that adverse environmental conditions can cause tillers to be omitted or delayed, but main stem leaves are produced at a rate not determined by the environment. Therefore, the number of tillers per plant can be used to indicate seedling stress. The number of main stem leaves per plant indicate rate of emergence. Plots were monitored throughout the growing season for plant growth and disease stress.

Drill Component Effects on Atrazine Toxicity

Separate experiments were conducted to evaluate the use of concave discs or the use of modified hoe openers to remove atrazine treated soils from the drill rows. The concave disc experiment to move atrazine soils from the row was located at the Lake Carl Blackwell Experimental Range Area, Stillwater, OK, in a McLain-Drummond complex soil (thermic Pachic Argiustolls-thermic Typic

Natrustolls). Openers used were spear point openers on 25 cm row spacings (hoe opener), double disc openers on 25 cm row spacings (double disc opener), and the 56 cm concave disc followed by paired spear point openers (concave disc paired hoe opener). The 46 cm coulter with depth bands and the 2.5 by 25.0 cm press wheels were used with all openers. Atrazine rates tested were 0.6, 1.1, 2.2, and 3.4 kg/ha. In addition, one treatment consisted of glyphosate (N-(phosphonomethyl) glycine) applied preemerge at 1.1 Kg/ha preemergence. Atrazine was applied on October 15 and plots were planted on October 17, 1984 with TAM 105 (Triticum aestivum L.) wheat.

A group balanced block in a strip plot design was used in this test (Gomez and Gomez, 1983). Planter combinations were evaluated in one strip, and atrazine rates were evaluated in the second strip. Initial emergence was recorded and plant growth was monitored throughout the growing period to determine effects of atrazine toxicity to wheat and weeds.

In the experiments conducted to evaluate use of modified hoe openers (the modified hoe experiment), the openers used included the spear point opener, 5 cm winged hoe opener, and 10 cm winged hoe opener. Press wheels used were a 2.5 cm by 25.0 cm press wheel, and a 10 cm by 30 cm rubber tire Vee type press wheel with springs to adjust down pressure.

The modified hoe experiments was conducted at two locations: the Agronomy Research Station, Perkins, OK, on a Teller loam (thermic Udic Argiustolls; the Teller loam location) and the Lake Carl Blackwell Experimental Range Area, Stillwater, OK, on a Port loam (the Port loam location). At both locations, atrazine was broadcast sprayed at 0.0, 0.6, 1.1, 2.2, and 3.4 kg/ha and planted. Plots were planted with Natadorus spring wheat (Triticum aestivum L.) on March 14, 1985 at the Teller loam location and March 15, 1985 at the Port loam location. A group balanced block in a strip plot design with one strip having two factors was used. The two factors evaluated in one strip were drill openers and press wheels. Atrazine rates were evaluated in the second strip. Both experiments were harvested on July 2, 1985.

RESULTS AND DISCUSSION

Component Effects on Seed Environment

With the exception of the concave paired disc treatment on the first date of planting at the minimum till location, there were no significantly different (0.05 level) values for number of mainstem leaves for either tillage system (Table 1 and 2). All mean comparisons were made with Duncan's new multiple range test. The drill opener type and spacing and the use of the concave disc did not affect stand as determined by use of Klepper's et al. (1982) rating system. Main stem leaves and numbers of tillers were not counted for the second date of planting in the minimum tillage experiment because the site remained muddy as a result of excessive rainfall. The concave disc hoe opener was not used on the first planting date in the minimum tillage experiment because limited clearance between the disc and the hoe opener caused the drill to plug with wheat straw. Component spacings were increased and this drill configuration did not plug during planting on the second date.

Only the hoe opener in the first planting date in the no-till experiment had significantly more tillers than the other planter treatments for either tillage system (Table 1 and 2). However, the paired row treatments tended to rank lower than the evenly spaced treatments for both planting dates in the no-till experiment and the first planting date in the minimum till experiment. This indicates that the wheat in paired rows may have been under higher stress early in the season according to the Klepper et al. rating method.

Paired spacing significantly reduced yields. The concave paired hoe opener ranked significantly lower than all other drill treatments in the first date of planting in the no-till experiment (Table 1). The paired hoe, concave disk paired hoe, and concave disc paired double disc treatments ranked significantly lower than the other drill treatments in the second planting date. No significant difference in yields were shown for the first planting date in the minimum tillage experiment, but all paired row treatments ranked lower than the uniformly spaced treatments (Table 2). For the second planting date in the minimum tillage experiment, the concave disc paired hoe and concave disc paired double disc treatments wheat yields ranked significantly lower than all other treatments.

Rain water was observed to stand for longer periods in furrows created by both concave disc paired opener treatments. Ponding stunted or drowned wheat in some plots. Maturity was delayed up to two weeks in some of the concave disk paired row treatments. Soil erosion was also observed where water was channeled by the 56 cm diameter concave disc furrow. Early in the growing season, reduction in residue borne diseases were observed where the concave disk removed residue with the treated soil. These reductions were not apparent later in the growing season.

Drill Component Effects on Atrazine Toxicity

In the experiment comparing effects of using the concave disk with paired hoe openers to improved atrazine selectivity, plant stands obtained with the three openers were not significantly different when no atrazine was applied (Table 3). Application of atrazine at 0.6 and 1.1 kg/ha reduced wheat stands only when wheat was seeded with the double disc opener.

Both drill type and herbicide treatment had significant effects on grain yield (Table 3). At the time of seeding, much of the cheat present had emerged. By comparing yields obtained by seeding with the concave paired hoe opener with the hoe and double disc openers in the check, it is apparent that the concave disc destroyed enough cheat to prevent yield reduction from this weed. With this opener, only the highest atrazine rate (3.4 kg/ha) reduced wheat yield. With the other openers, application of glyphosate after seeding to kill existing cheat increased wheat yields substantially. Compared to the check, application of 0.6 or 1.1 kg/ha of atrazine also increased yield. However, in contrast to the concave disc paired hoe opener, yield reductions occurred when atrazine was applied at 2.2 kg/ha.

In the modified hoe experiment, atrazine had a highly significant (PR>F=0.0004) effect on plant stand on the Teller loam, with increasing atrazine rates causing decreasing stands. All analyses of variance were made with the PROC ANOVA procedure from the SAS (1979) statistical package. SAS reports the actual significance probability. Significance probability for each main factor on or interaction discussed is recorded in parenthesis. Atrazine effect on wheat stand was also highly significant (PR>F=0.0001) on the Port loam.

Openers significantly affected wheat stands on both the Teller loam (PR>F=0.0206) and the Port loam (PR>F=0.0281). The 10 cm winged hoe had significantly better stands than the 2.5 cm hoe on the Teller loam (Table 6). Both the 5 cm and 10 cm winged hoe had significantly better stands than the 2.5 cm hoes on the Port loam (Table 6).

Press wheels significantly affected wheat stands on both the Teller loam and the Port loam. On the Teller loam, Vee press wheel stands averaged 6.9 plant/row m and 2.5 by 25 cm stands averaged 4.9 plants/row m (PR>F=0.0620). On the Port loam, Vee press wheel stands averaged 26.9 plants/row m and 2.5 by 25 cm press wheel stands averaged 23.3 plants/row m (PR>F=0.0643).

There was a significant (PR>F=0.0113) atrazine application rate by opener interaction for wheat stand on the Teller loam. There was also a significant (PR>F=0.0110) atrazine rate by press wheel interaction for wheat stand factor on the Teller loam. The atrazine rate by opener by press wheel interaction for wheat stand was a significant factor (PR>F0.0152) on the Port loam. The 10 cm winged hoe openers with both press wheel types were not significantly different from the best check stands for application rates as high as 1.1 kg/ha on the Teller loam (Table 4). There were no significant differences in wheat stands among the 5 and 10 cm winged hoe treatments with Vee press wheels and the best check stands for atrazine rates as high as 2.2 kg/ha on the Port loam (Table 5).

Atrazine application rate was a highly significant factor decreasing forage yield on the Teller loam (PR>F=0.0003) and on the Port loam (PR>F=0.0001). Press wheels were a significant factor (PR>F=0.0287) affecting forage yield on the Teller loam. The 2.5 by 25 cm treatments averaged 42.1 kg/ha, while the Vee press wheel treatment averaged 65 kg/ha for all atrazine rates and openers. Openers significantly (PR>F=0.0392) affected forage yield on the Port loam. The 10 cm winged hoe treatment averaged over all atrazine and press wheel treatments, ranked significantly higher than the other openers on the Port loam (Table 6). The 10 cm winged hoe treatment also ranked higher on the Teller loam but the difference was not significant. On the Teller loam, the 5 cm and 10 cm winged hoes with the Vee press wheels forage yields were not significantly different from the best check treatments for rates as high as 1.1 kg/ha (Table 4). On the Port loam, both 10 cm winged hoe treatments forage yields were not significantly different from the best check treatments for rates as high as 2.2 kg/ha (Table 5).

Atrazine rate was a highly significant factor affecting grain yields (PR>F=0.0001 on both soils) with increasing atrazine rates causing decreased yields. Drill opener and press wheel main factors and interactions were not significant for wheat yields. No significant trends or patterns could be detected among treatment means using Duncan's analysis. Normally, spring wheat is not grown in Oklahoma. The wheat was planted three weeks late because of wet soils. The weather was hot and dry during grain filling and there appeared to be a substantial disease problem. The combination of these factors depressed grain yields and minimized differences between treatments.

Soil type appeared to have a substantial effect on the maximum allowable atrazine rate. In the Port loam (32% sand, 42% silt, 26 % clay) the 10 cm winged hoe and Vee press wheel could be used with atrazine rates as high as 2.2 kg/ha without significant decrease in wheat stand (Table 5). However, in the Teller loam (56% sand, 26% silt, 19% clay), the 10 cm hoe and Vee press wheel could only be used with atrazine rates no higher than 1.1 kg/ha without significant reductions in wheat stand and forage yield (Table 4). A similar relationship existed for most other opener, press wheel combinations.

SUMMARY AND CONCLUSION

Atrazine treated plots sown with the 56 cm concave disc followed by paired spear point hoe openers had significantly higher wheat stands and yields than spear point hoe and double disc openers at 25 cm row spacings. Plots planted in atrazine treated soil with the 10 cm winged hoe and the Vee press wheel produced higher stands and more forage than plots sown with a spear point hoe, or 5.0 cm winged opener. However, drill component tests on untreated soil indicated that planting with the double disc or spear point hoe openers in paired row spacings with and without the 56 cm concave disc openers caused lower yields than 25 cm row spaced openers. Plots planted with the concave disk paired opener combinations were more susceptable to soil erosion and ponding. Therefore, the best combination of drill components for removing atrazine treated soil was the 46 cm gauge coulter, 10 cm winged hoe opener and Vee press wheel combination which removed a 10 cm wide strip of atrazine treated soil from the row.

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Table 1. Response of no-till wheat to drill unit configuration.

Drill[1]	Main Stem Leaves/row m		Tillers per plant		Grain Yield kg/ha	
	Oct 2[2]	Oct 19	Oct 2	Oct 19	Oct 2	Oct 19
Hoe	279 a[3]	288 a	4.6 a	1.7 a	1979 ab	1555 ab
Double Disc	292 a	270 a	3.3 b	2.3 a	2006 ab	1671 ab
Concave Hoe	284 a	282 a	3.0 b	2.0 a	2262 a	1867 a
Paired Hoe	283 a	294 a	2.7 b	1.9 a	1740 ab	1513 b
Concave Paired Hoe	291 a	285 a	2.8 b	1.9 a	1670 b	1566 ab
Concave Paired Disc	210 a	276 a	2.6 b	1.9 a	1929 ab	1517 b

1. Hoe - spear point hoe opener on 25 cm row spacings; double disc - double disc opener on 25 cm row spacings; paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings; concave hoe - spear point hoe openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc; concave paired disc - double disc openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc.

2. Date of planting.

3. Means preceded by the same letter are not significantly different at the 0.05 level as indicated by Duncan's new multiple range test.

Table 2. Response of minimum-tilled[1] wheat to drill unit configuration.

Drill[2]	Main Stem Leaves/row m	Tillers per plant	Grain Yield kg/ha	
	Oct 11[3]	Oct 11	Oct 11	Nov 6
Hoe	288 a[5]	2.7 a	1456 a	1451 ab
Double Disc	270 a	2.6 a	1412 a	1717 a
Concave[4] Hoe	-----	-----	------	1567 a
Paired Hoe	294 a	2.2 a	1475 a	1393 ab
Concave Paired Hoe	285 a	2.3 a	1323 a	1060 bc
Concave Paired Disc	276 a	2.3 a	1348 a	827 c

1. Undercut with V-blade; tilled with rod weeder and mulch tiller to control weeds.

2. Hoe - spear point hoe opener on 25 cm row spacings; double disc - double disc opener on 25 cm row spacings; paired hoe - spear point hoe openers on alternating 13 and 38 cm row spacings; concave hoe - spear point hoe openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc; concave paired disc - double disc openers on alternating 13 and 38 cm row spacings with each pair preceded by a 56 cm concave disc.

3. Date of planting; excessive rainfall prevented collection of main stem leaf and tiller data for November 6 planting.

4. 46 cm concave disc followed by the single hoe opener plugged repeatedly in the loose straw on the October 11 planting; component spacings were changed to enable planting in the straw on November 6.

5. Means followed by the same letter are not significantly different at the 0.05 level as indicated by the Duncan new multiple range test.

Table 3. Effect of using a concave disk followed by paired spear point hoe openers to remove atrazine treated soil compare to double disc and spear point openers i no-till wheat.

Herbicide Treatment		Wheat Stand Plants/row m			Wheat Yield kg/ha		
Herbicide	Rate kg/ha	Concave[1] Disc	Double Disc	Spear Pt. Hoe	Concave Disc	Double Disc	Spear Pt Hoe
Check	---	49 a-c	42 a-d	41 a-d	1597 a-c	843 df	1077 b-
Atrazine	0.6	58 a	38 b-d	49 a-c	1896 a	1699 ab	1708 ab
Atrazine	1.1	57 a	33 cd	42 a-d	1745 a	1364 a-d	1868 a
Atrazine	2.2	39 b-d	14 ef	18 ef	1414 a-d	331 f-g	713 e-
Atrazine	3.4	25 de	3 f	11 ef	1045 c-e	34 h	168 gh
Glyphosate[2]	1.1	47 a-c	40 b-d	51 ab	1810 a	1764 a	1797 a

1. Paired spear point openers following concave disc on alternating 13 and 38 cm row spacings; double disc and spear point hoes on 25 cm spacings with both opener preceded by a disc coulter.

2. Glyphosate applied pre-emerge.

3. Means followed by the same letter are not significantly different at the 0.05 level as indicated by Duncan's new multiple range test.

Table 4. Response of spring wheat to width of the strip of atrazine treated soil removed by the hoe opener and to press wheel type in a Teller loam (56% sand, 26% silt, 19% clay).

Opener Width cm	Press[1] Wheel	Appli. Rate kg/ha	Wheat Stand plants/row m	Forage Yield kg/ha	Grain Yields kg/ha
2.5	2.5	0.0	6.0 b-f[2]	85 a-f	165 a-e
2.5	Vee	0.0	12.2 a-e	104 a-e	155 a-f
5.0	2.5	0.0	7.4 a-f	52 d-g	189 a-c
5.0	Vee	0.0	13.6 a-c	125 a-d	231 ab
10.0	2.5	0.0	12.8 a-d	136 ab	233 a
10.0	Vee	0.0	15.4 a	137 ab	227 a-c
2.5	2.5	0.6	3.7 f-h	65 b-g	148 b-f
2.5	Vee	0.6	6.0 b-h	58 c-g	178 a-d
5.0	2.5	0.6	6.0 b-h	45 e-g	167 a-e
5.0	Vee	0.6	14.0 ab	131 a-c	196 a-c
10.0	2.5	0.6	10.7 a-g	86 a-f	218 a-c
10.0	Vee	0.6	14.6 a	146 a	205 a-c
2.5	2.5	1.1	4.2 e-h	34 e-g	94 e-h
2.5	Vee	1.1	5.0 d-h	53 d-g	76 f-i
5.0	2.5	1.1	5.9 b-h	38 e-g	92 e-h
5.0	Vee	1.1	5.4 c-h	98 a-e	98 d-g
10.0	2.5	1.1	10.2 a-g	51 d-g	145 c-f
10.0	Vee	1.1	11.9 a-f	94 a-c	145 c-f
2.5	2.5	2.2	0.8 h	10 fg	29 g-i
2.5	Vee	2.2	1.2 h	8 fg	24 g-i
5.0	2.5	2.2	0.7 h	16 fg	26 g-i
5.0	Vee	2.2	0.8 h	10 fg	30 g-i
10.0	2.5	2.2	0.7 h	6 g	31 g-i
10.0	Vee	2.2	0.7 h	8 fg	20 g-i
2.5	2.5	3.4	1.4 h	1 g	8 i
2.5	Vee	3.4	0.2 h	1 g	11 hi
5.0	2.5	3.4	2.5 h	2 g	4 i
5.0	Vee	3.4	1.5 h	1 g	8 i
10.0	2.5	3.4	0.9 h	5 g	5 i
10.0	Vee	3.4	0.7 h	1 g	2 i

1. 2.5 - 2.5 by 25 cm press wheel; Vee - 10 by 25 cm Vee profile press wheel.
2. Means followed by the same letter are not significantly different at the 0.05 level as indicated by Duncan's new multiple range test.

Table 5. Response of spring wheat to width of the strip of atrazine treated soil removed by the hoe opener and to press wheel type in a Port loam (32% sand, 42% silt, 26% clay).

Opener Width cm	Press[1] Wheel	Appli. Rate kg/ha	Wheat Stand plants/row m	Forage Yield kg/ha	Grain Yields kg/ha
2.5	2.5	0.0	24 c-f[2]	330 a-f	424 ab
2.5	Vee	0.0	30 a-d	340 a-e	289 a-f
5.0	2.5	0.0	36 ab	334 a-e	474 a
5.0	Vee	0.0	30 a-d	347 a-e	480 a
10.0	2.5	0.0	29 a-d	355 a-e	348 a-e
10.0	Vee	0.0	34 a-c	459 a	480 a
2.5	2.5	0.6	29 a-d	369 a-d	324 a-f
2.5	Vee	0.6	24 c-f	340 a-e	291 a-f
5.0	2.5	0.6	32 a-d	348 a-e	405 a-c
5.0	Vee	0.6	37 a	380 a-c	388 a-d
10.0	2.5	0.6	30 a-d	435 a	381 a-d
10.0	Vee	0.6	34 a-c	420 ab	471 ab
2.5	2.5	1.1	22 c-g	256 a-i	234 a-f
2.5	Vee	1.1	26 a-e	289 a-h	266 a-f
5.0	2.5	1.1	30 a-d	322 a-f	242 a-e
5.0	Vee	1.1	37 a	296 a-f	447 ab
10.0	2.5	1.1	25 b-e	383 a-c	354 a-e
10.0	Vee	1.1	37 a	374 a-d	391 a-d
2.5	2.5	2.2	21 d-h	328 a-f	280 a-f
2.5	Vee	2.2	19 gh	221 b-i	266 a-f
5.0	2.5	2.2	13 f-h	201 c-i	204 b-f
5.0	Vee	2.2	26 a-e	194 c-i	324 a-f
10.0	2.5	2.2	16 e-h	289 a-h	332 a-f
10.0	Vee	2.2	27 a-e	284 a-h	280 a-f
2.5	2.5	3.4	15 e-h	123 f-i	144 c-f
2.5	Vee	3.4	13 f-h	87 hi	99 ef
5.0	2.5	3.4	11 h	72 i	78 f
5.0	Vee	3.4	12 gh	156 e-i	135 d-f
10.0	2.5	3.4	16 e-h	112 g-i	95 ef
10.0	Vee	3.4	17 e-h	167 d-i	145 c-f

1. 2.5 - 2.5 by 25 cm press wheel; Vee - 10 by 25 cm Vee profile press wheel.
2. Means followed by the same letter are not significantly different at the 0.05 level as indicated by Duncan's new multiple range test.

Table 6. Spring wheat stands and forage yields on two soil types[1] for three drill openers with stands averaged over five atrazine application rates[2].

Opener[3] Width cm	Stand Plant/row m Teller loam	Stand Plant/row m Port loam	Forage Kg/ha Teller loam	Forage Kg/ha Port loam
2.5	4.1 A[4]	22.3 A	42 A	268 A
5.0	5.8 A	26.4 B	52 A	265 A
10.0	7.9 B	26.5 B	67 A	328 B

1. Teller loam - 56% sand, 26% silt, 19 % clay.
   Port loam - 32% sand, 42% silt, 26% clay.

2. Atrazine application rates - 0.0, 0.6, 1.1, 2.2, 3.4 kg/ha.

3. Opener width - width of strip of atrazine treated soil removed by a spear point hoe, a 5 cm winged hoe, and a 10 cm winged hoe.

4. Means followed by the same letter are not significantly different at the 0.05 level as indicated by Duncan's new multiple range test.

Figure 1. No-Till drill with pneumatic seed delivery system coulter guage wheels, spear point hoe openers, and 2.5 by 25.0 cm press wheels

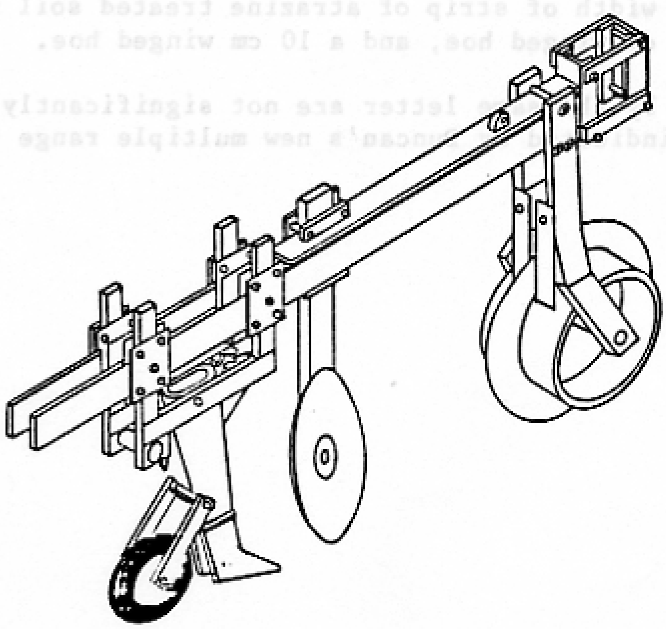

Figure 2. Single drill unit with coulter guage wheel, 46 cm diameter concave disc to remove atrazine treated soil, spear point hoe opener, and 2.5 x 25.0 cm press wheel.

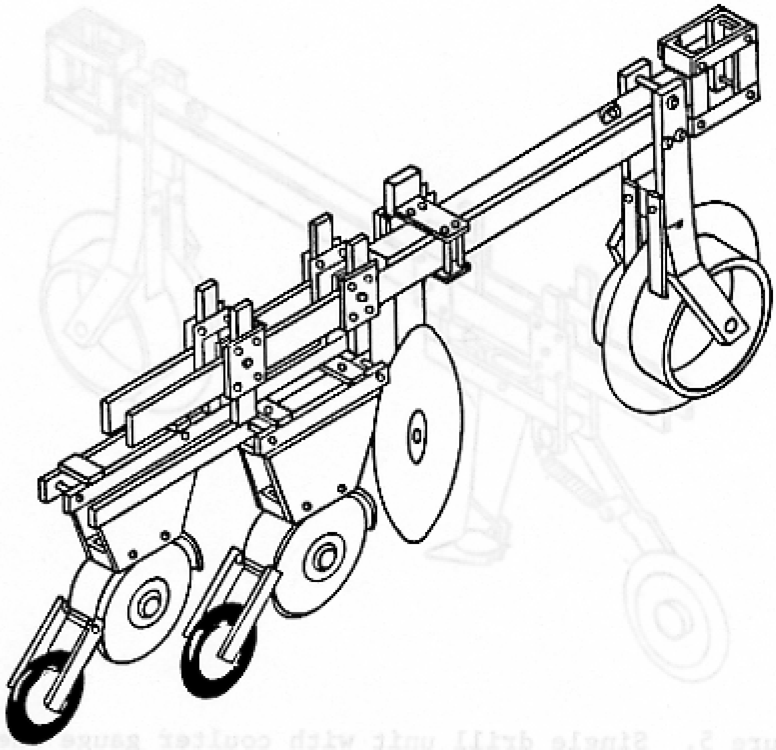

Figure 3. Single drill unit with coulter guage wheel 56 cm diameter concave disc to remove atrazine treated soil, paired double disc openers, and 2.5 by 25.0 cm press wheels.

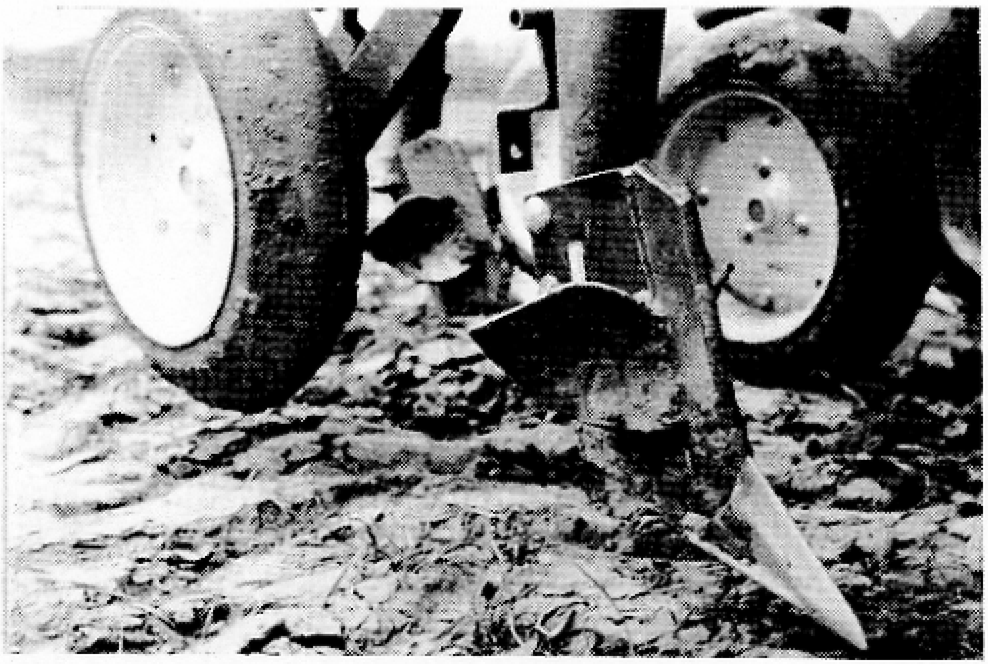

Figure 4. Winged spear point hoe opener designed to remove a 5 cm wide strip of atrazine treated soil and 10 by 30 cm Vee press wheel.

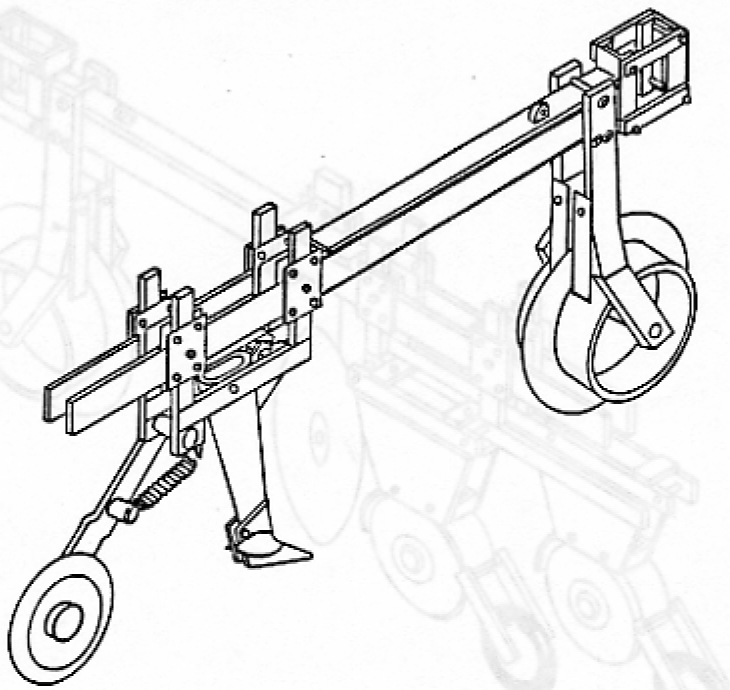

Figure 5. Single drill unit with coulter gauge wheel winged hoe to remove 5 cm wide strip of atrazine treated soil, and 10 by 30 cm Vee press wheel.